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# TITANIUM

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## REPORT

OF THE

## SUBCOMMITTEE ON NATIONAL STOCKPILE AND NAVAL PETROLEUM RESERVES

OF THE

## COMMITTEE ON ARMED SERVICES UNITED STATES SENATE

EIGHTY-FOURTH CONGRESS

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### SUBCOMMITTEE ON NATIONAL STOCKPILE AND NAVAL PETROLEUM RESERVES

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## LETTER OF SUBMITTAL

UNITED STATES SENATE,
COMMITTEE ON ARMED SERVICES,
*May 25, 1955.*

Hon. RICHARD B. RUSSELL,
*Chairman, Committee on Armed Services,*
*United States Senate, Washington, D. C.*

DEAR MR. CHAIRMAN: Attached please find a report on titanium made by your Subcommittee on National Stockpile and Naval Petroleum Reserves of the Senate Armed Services Committee.

We want to express our deep appreciation to Mr. Irving Gumbel for the long hours he spent helping us with this problem, at no cost to the Government—and also for the splendid assistance given the committee during the hearings and at all other times by Mr. William Darden of the committee staff.

The report speaks for itself.

Respectfully,

STUART SYMINGTON.
JAMES H. DUFF.

[COMMITTEE PRINT]

# REPORT ON TITANIUM BY THE SUBCOMMITTEE ON NATIONAL STOCKPILE, AND NAVAL PETROLEUM RESERVES, SENATE COMMITTEE ON ARMED SERVICES

(Senators Symington (chairman) and Duff)

## I. Introduction

Titanium has been termed a "miracle metal," and also the "metal of the future."

How miraculous, and how far in the future, is still not clear.

There are currently a number of unanswered questions concerning the usability of titanium on a wide scale.

Nevertheless, the United States Government, for the past several years, has been investing large sums in subsidizing a titanium production program.

This report is an effort to clarify the titanium picture; and also to present facts incident to current Government and private programs for research, development, and production of the metal.

To this end, the committee held hearings on March 17 and 28, and April 13 and 25 of this year.

## II. Description of Titanium

Titanium is a relatively strong, light, and corrosion-resistant metal. It possesses an unusual combination of properties: a strength, when alloyed, approaching that of high-strength steels; a density 60 percent heavier than aluminum, but only 56 percent as heavy as alloy steel; a strength-weight ratio in the intermediate temperature ranges (300° F.–800° F.) superior to that of either aluminum or alloy steel; and a corrosion resistance unsurpassed in any other metal for many purposes.

These characteristics have suggested possible substantial uses for titanium in aircraft, guided missiles, airborne and hand-carried military equipment, and industrial equipment designed to contain corrosive materials at high temperatures and pressures.

Titanium's immunity to salt water and marine atmospheres, combined with its apparent inherent strength when properly alloyed, indicates a number of uses for the metal in ship construction.

From the first industrial experimentation with titanium, however, certain obvious difficulties in the use of the metal were apparent: its extreme affinity for various other elements (oxygen, hydrogen, nitrogen, etc.); its hardness, making the metal difficult to work; its brittleness when contaminated by small quantities of other elements; and its fatigue under certain temperature conditions.

In 1947, when the Bureau of Mines announced the availability of a commercial method for producing ductile titanium (the Kroll proc-

ess), high temperature-resistant metals were crucially needed for jet engines.

Titanium, with its extra-high melting point of 3,020° F., at first seemed the perfect answer.

By 1950, however, metallurgists had discovered that pure titanium loses strength on continuous exposure to temperatures above 800° F.

Added to these disadvantages has been, and is, the high cost of titanium. Originally the cost was $10,000 per ton for titanium sponge and $20,000 to $50,000 per ton for mill products.

These prices have been reduced somewhat, as will be detailed later in this report.

## III. Titanium Ore Deposits

Titanium is the fourth most abundant structural metal in the crust of the earth. Its supply is exceeded only by aluminum, iron, and magnesium. It ranks ahead of copper, lead, and zinc.

Ore deposits and beach sands throughout the world are known to contain large quantities of titanium, many of which were developed years ago to supply the paint pigment industry.

Abundant deposits of titanium ore on the North American Continent are now known. The mineral occurs generally as ilmenite or rutile.

Ilmenite is a titanium-iron-oxygen-bearing ore ($TiFeO_3$), found chiefly in New York, Minnesota, Wyoming, Montana, California, and North Carolina. (Most other States also contain ilmenite deposits which might some day become commercial.)

Rutile is a titanium-oxygen-bearing ore ($TiO_2$), the largest North American deposits of which are in Florida, Arkansas, Virginia, and New Mexico.

Some high-grade rutile has been imported from Australia, where it occurs in beach sands.

Contracts between the Government and private companies require that each plant sponsored by the Government must be capable of operating on domestic ores, thus affording a strategic security in case of emergency.

## IV. Processing of Titanium

The commercial production of titanium was begun in 1948.

The first sponge plants were built by the Bureau of Mines and E. I. du Pont de Nemours & Co., using the Kroll process. Also, in the early period of the industry, a number of companies began experimental production of metal melting and fabrication on a small scale. Aircraft and engine companies started experimental use of titanium.

All commercial production of titanium today is by the Kroll process. Basically this involves the magnesium reduction of titanium tetrachloride at a red heat under an inert gas blanket.

The tetrachloride used in this process is produced by chlorination of titanium dioxide obtained from the two ores, ilmenite and rutile.

The Kroll process produces a commercially pure spongy metal known as titanium sponge.

A new plant is in construction involving a process differing somewhat from the Kroll method. This is a sodium reduction of titanium tetrachloride, rather than the presently used magnesium reduction. This second method will also produce sponge.

Titanium sponge is consolidated into ingots by melting. The most successful process today involves a double melting, consumable electrode, vacuum process.

The resulting ingot is further worked into billet, bar, rod, sheet, and other basic mill shapes.

## V. Government Sponge Production Requirements

Since 1952, and until quite recently, the Department of Defense has been urging that domestic production of sponge be increased to 35,000 tons annually.

According to Defense Department testimony at the April 25 hearing of this subcommittee:

> The 35,000-ton figure was the result of computations which, in turn, were based on thousands of individual engineering estimates as to where titanium would be used, in what amounts, and by what time. There was obviously an attempt here to look ahead and look forward as to what areas that might be used, if they were able to get over these various technical difficulties in working with the metal.

Also according to Defense Department testimony at the same hearing:

> It is our understanding that ODM at no time established a formal goal of 35,000 tons. * * * However, we believe that since early 1954 ODM * * * was prepared to move on, upward to 35,000 tons as soon as acceptable proposals were developed.
>
> The Department of Defense maintained its recommendation until 9 December, 1954, at which time we recommended no further expansion beyond the amount then authorized or for which commitments had proceeded beyond the point of withdrawal. By this we meant the 22,500 tons then under contract.
>
> However, the language of our letter was such as to possibly permit other interpretation, depending upon what tonnage ODM considered to be authorized at that time.

At the March 28 subcommittee hearing, however, an ODM representative stated that an annual 35,000-ton titanium sponge production goal was "the general understanding at the present time." He also stated that 22,500 tons annually were under contract.

An ODM report on titanium (March 25, 1955) stated that—

> within the executive agencies * * * there has emerged general agreement—

that—

> the Government, through the General Services Administration, should continue to encourage domestic producers to expand sponge capacity beyond the present 22,500 annual tons, but should emphasize improved sponge quality and decreased sponge cost in developing new contracts.

## VI. Expansion of Sponge Production

Government policy on titanium production was described as follows in the March 1955 ODM titanium report:

> Although the inherent advantages of titanium as a military material were immediately recognized—particularly in the design of high-performance aircraft—its use by the aircraft industry in the early days was retarded by the fear that insufficient metal would be available to support the contemplated applications.
>
> Therefore, the Government undertook in 1952 a rapid expansion of sponge-producing facilities under the enabling legislation of the Defense Production Act.

Statistics incident to titantium activities in recent years follow:

[All figures from ODM report, March 25, 1955]

| *Sponge-production statistics* | *Short tons* |
|---|---|
| 1952 (actual) | 1,075 |
| 1953 (actual) | 2,241 |
| 1954 (actual) | 5,370 |
| 1955 (estimated) | 10,000 |
| 1956 (estimated) | 17,500 |
| 1957 (estimated) | 22,500 |

| *Domestic companies participating in the Government program (with annual capacities of their facilities)* | *Short tons* |
|---|---|
| Du Pont | 3,600 |
| Titanium Metals Corp | 3,600 |
| Cramet, Inc | 6,000 |
| Dow Chemical Co | 1,800 |
| Electro Metallurgical Co. (Union Carbide & Carbon) | 7,500 |
| Total | 22,500 |

| *Additional projects currently under negotiation* | *Short ton* |
|---|---|
| Du Pont | 7,200 |
| Titanium Metals Corp | 5,400 |
| Harvey Machine Co | 4,000 |
| Western Pyromet | 6,000 |
| Wah Chang Trading Corp | 6,000 |
| Kennecott Copper Co | 1,000 |
| Aero Metals | 1,000 |
| Total | 30,600 |
| Already under contract | 22,500 |
| Grand total | 53,100 |

According to the same ODM report:

In contrast to the sharp increase in production of sponge, the utilization of titanium in the last few years has progressed only moderately.

The statistics on shipment of mill products follow:

| | *Tons* |
|---|---|
| 1953 (actual) | 1,114 |
| 1954 (actual) | 1,299 |
| 1955 (estimate) | 1,500 |

## VII. Government Titanium Production Contracts

The General Services Administration negotiated 5-year contracts with Titanium Metals Corporation of America (TMCA) (August 1, 1951) for a 3,600-ton plant; with the Du Pont Co. (July 24, 1952) for a 2,700-ton plant (Du Pont was already operating a 900-ton plant, constructed privately); and with Cramet, Inc. (July 31, 1953) for a 6,000-ton plant.

In each case, the Government agreed to advance funds—$15,000,000 to Titanium Metals Corp; $14,700,000 to Du Pont; and $24,950,000 to Cramet—to be repaid with interest at 4 percent, at a rate of so much per pound of metal produced and sold. The rate is determined by dividing the amount advanced by the Government by five times the annual rated capacity of the facilities.

In the event of the inability of the contractor to operate at a profit, he is authorized to convey the plant to the Government in entire

satisfaction of unpaid indebtedness. In the case of Du Pont and Titanium Metals Corp., the Government would be required to remove facilities from the contractor's land; in the case of Cramet, the Government would receive fee simple title to the plant.

In general, the Government is required to purchase all output which cannot be sold to users at the market price at the time of delivery; this with the exception of Dow and Cramet. The latter company may tender the first 1,000 tons of the first year's production at $10,000 per ton, and 5,000 tons additional at $8,000 per ton.

Until the Du Pont and TMCA plants came into substantial production, there was an acute shortage of titanium. The metal was, and still is, under 90 percent allocation for military uses.

In November 1953, the Subcommittee on Minerals, Materials, and Fuels Economics of the Senate Interior and Insular Affairs Committee began hearings on titanium.

Numerous witnesses were heard, including sponge producers, fabricators, plane and engine manufacturers, and civilian and Government officials.

For the most part, their testimony indicated a growing need for titanium. Estimates up to 150,000 tons per year of titanium requirements were presented.

In the spring of 1954, the General Services Administration increased its efforts to contract for additional production. Three companies were found prepared to build plants.

Opinion regarding the approaching obsolescence of the Kroll process had changed, and the following contractors were prepared to finance construction with corporate funds, provided the Government would grant accelerated amortization and guarantee a market for the output:

Dow Chemical Co. was prepared to construct a 1,800-ton per year plant, Union Carbide & Carbon one of 7,500 tons per year, and Du Pont an additional plant of 7,200 tons per year.

These projects were certified to GSA by ODM and contracts were executed with Dow on July 5, 1954; and with Union Carbide & Carbon on September 14, 1954.

The Du Pont contract has been negotiated, but not yet executed.

The Dow contract terms varied from the others, in that the Government's obligation to purchase was limited to 1,000 tons, and the price fixed at $10,000 per ton.

During the course of these negotiations a number of other prospective contractors appeared and preliminary negotiations were undertaken with them.

In the meanwhile, consumption of titanium was not reaching expected proportions.

Manufacturers found great difficulty in working the metal—particularly in its fabrication.

By the fall of 1954, the producers found themselves unable to dispose of their entire production of sponge.

The General Services Administration thereupon contracted to purchase all excess sponge at the market price.

The failure in the carrying out of the previously estimated demand for titanium was due to a number of factors. Among them were—

1. Lack of alloys with the required physical characteristics.
2. Lack of uniformity of product.
3. Excessive rejections.

4. Inability to utilize the resulting scrap.
5. Difficulty in forming titanium on equipment not designed for that purpose.
6. Excessive costs resulting from the above factors, along with the very high price of titanium sponge.

## VIII. Research and Development

In the early years of titanium development most of the research was performed by private companies with limited funds. Some work was sponsored by the three armed services.

In February 1954, the Director of ODM established an Advisory Committee on Titanium composed of Dr. Herbert Kellogg, professor of metallurgy at Columbia University, Dr. A. J. Phillips, vice president of research and development, American Smelting & Refining Co., and Mr. Felix Wormser, Assistant Secretary of the Interior.

The committee was given little, if any, authority, and met infrequently.

In August 1954, a steering group on titanium research and development was set up in the Office of the Assistant Secretary of Defense (Research and Development), composed of members of the three services.

During the following 9 months, the committee finalized a proposal which had been pending with the Battelle Institute of Columbus, Ohio, for the establishment at the institute of a laboratory to provide technical advice to Government contractors by:

1. Collecting and disseminating information on research and development of titanium.
2. Providing technical advisory service to producers and users of titanium.
3. Providing advice and assistance to the steering group in its appraisal of the research and development program of the Defense Department.
4. Helping in developing specifications.
5. Conducting short-range laboratory investigations

## IX. Titanium Stockpile

The Government has been purchasing, at the market price, titanium sponge produced in excess of current consumption, and has been holding that sponge in a revolving inventory financed with Defense Production Act funds.

As of December 31, 1954, according to ODM, 2,894 tons of currently acceptable specification sponge had been added to this inventory.

Based on present estimates, it seems probable another 5,000 tons will be acquired during this year.

In addition to the aforementioned program, titanium sponge has been declared a strategic and critical material within the meaning of Public Law 520; and an interim stockpile objective has been established. According to the March 1955 ODM titanium report:

> After accumulation of an adequate reserve supply in the revolving inventory, quantities of sponge of the higher qualities that become available will be moved into this stockpile.

It is not known (1) what is the definition of "higher quality"; or (2) what will happen to the sponge which is not of that quality.

## X. Nature and Extent of Government Liability

There are so many unknown factors and alternate possibilities that it is impossible to calculate accurately the actual cost of the titanium program to the United States Government.

However, various commitments which the Government has assumed are as follows:

1. *GSA revolving fund.*—Under this program, slightly less than 4,000 tons of titanium sponge have been acquired to date at an average cost of approximately $9,000 per ton, or a total cost of $36,000,000.

At the present market price, these purchases show an apparent loss of $1,100 per ton, or a total of about $4,400,000. A further loss will be sustained if the price of titanium is further reduced before this stock is sold or consumed.

In addition, GSA has contracted to purchase, at market price at time of delivery, an additional 1,100 tons through June 30, 1955, and has authority to increase this amount to 4,000 tons—an amount which is expected to take care of excess production through June 30, 1956.

2. *Du Pont Co.*—The Government advance in the case of Du Pont has been reduced, by repayments, to about $8,000,000, the maximum amount for which the Government is liable in the event the contractor decides to cease operations.

3. *TMCA.*—The Government advance to this company now amounts to $12,000,000. The situation is identical to that existing with Du Pont.

4. *Cramet, Inc.*—The Government advance in this case amounts to $25,000,000. The Government is committed to purchase from the company 1,000 tons at $10,000 per ton, and 5,000 tons at $8,000 per ton. The apparent loss on these purchases at today's prices is $2,600,000.

If the company decided to discontinue operations when this quantity of titanium was produced, the outstanding indebtedness to the Government, which would then amount to about $20,000,000, would be canceled. The Government would acquire the plant.

5. *Dow Chemical Co.*—The Government commitment in this case is to purchase 1,000 tons of titanium at $10,000 per ton. At current prices, this indicates a $2,100,000 loss.

6. *Union Carbide & Carbon.*—The Government may cancel this contract after 1 year's operation. In that case, the Government would have to assure the sale of 7,500 tons of titanium at the then existing market price, and also pay the contractor approximately $31,000,000. The latter figure is the estimated unamortized cost of the property at the end of 1 year's operation.

## XI. Titanium Prices

In general, the GSA titanium expansion contracts provide that the Government guarantee a market for the entire production of each contractor.

The problem of establishing a price for such purchases presented considerable difficulty. It was finally determined that the price would be the lower of (1) the current market price, or (2) the lowest price at which the contractor was currently selling to others.

In both cases it was recognized that the Government would be at the mercy of the small number of producers. It was thought, however, that this danger could be minimized by the Government's right to offer the metal for resale at lower prices. It was felt this operation would reduce the quoted market price, and therefore compel the producers to make future sales at those lower prices.

In the case of titanium, prices were established at first by the Du Pont Co., with TMCA following its lead.

Until April 1954, all titanium sponge was sold at $10,000 per ton. At that time, Du Pont established two grades: A–1, which contains less than 0.30 percent iron, and was offered at $9,440 per ton; and A–2, containing more iron, and selling at $8,920 per ton.

In September 1954, Du Pont lowered its prices to $9,000 and $8,000 per ton, respectively.

In April 1955, TMCA took the initiative in price setting on titanium by reducing the price to $7,900 per ton. The Du Pont Co. immediately met this move by establishing prices of $7,900 per ton for A–1 sponge and $7,000 per ton for A–2.

It was presumed this cut in sponge price would be reflected in varying reduced prices for mill products. Those prices have ranged from approximately $20,000 to $40,000 per ton in shaped forms, with titanium wire running much higher.

## XII. Problems Presented by the Titanium Picture

On the basis of testimony and information made available to the subcommittee, the current titanium program contains a number of problems. These include:

1. Production is running far ahead of demand.
2. The Government is underwriting almost the entire cost of the program.
3. Despite this Government subsidy, the companies involved restrict the exchange of information incident to improvements and discoveries in the field of titanium.
4. Insufficient research has been done on titanium, both as to process and use.
5. Prices may or may not be related to costs. The Government does not have that knowledge.
6. There is unnecessary security classification of titanium data. This policy has had much to do with the expenditure of unnecessary funds.
7. The Government program has no centralized control.

As an example of this lack of coordination, in January 1954 the Office of Defense Mobilization instructed the General Services Administration to enter into a contract with the Du Pont Co.; a contract which would allow that company to proceed immediately with the design of a new 7,200-ton-per-year sponge plant.

It was estimated this work would require 6 months, and cost approximately $600,000.

Concurrently, the parties were to negotiate a procurement contract as a basis for the construction of the facilities.

In the event an agreement could not be reached, the Government agreed to pay Du Pont the cost of the engineering and design of the plant, said cost not to exceed $600,000.

The Government retained no rights to the design. The latter remained the exclusive property of Du Pont.

This extraordinary contract was justified on the grounds of national urgency.

The contract has not yet been signed, because by the time ODM finally gave its approval, the contractor was doubtful of the necessity of the project.

The original cutoff date for execution of the procurement contract of January 1954 was set as of September 1, 1954. Since then it has been amended five times. It is now established as of July 31, 1955.

Another illustration of interagency confusion is the current status of a number of development projects for sponge, scrap melting, and fabrication which were submitted by various firms to both GSA and the Department of Defense over a year ago.

Both agencies have responsibility in the titanium field. Apparently, however, the Department of Defense lacks funds; while GSA, amply financed through the Defense Production Borrowing Authority, has no authority to sponsor such projects.

The ODM titanium report of March 1955 stated:

> It seems clear today that the development of titanium fabrication know-how has not kept pace with the expansion of the production of titanium sponge.
>
> This would suggest that the titanium program has reached a crossroad. It becomes evident that the Government must either (1) provide additional assistance as may be required to speed up commercial-scale application of titanium to military components, or (2) slow down its expansion program of titanium sponge production.

A December 1954 report by the Assistant Secretary of Defense for Research and Development pointed out that "The large orders for production quantities of titanium which had been expected by now have not been forthcoming." and cited as reasons, the limited quantity of titanium in the form of metal that could be fabricated, the fact that engineering properties of the metal are "still unfamiliar," "technical deficiencies that have cropped up," and high cost.

## XIII. Conclusions and Recommendations

As a result of these hearings, it is evident that the Government, by assuming substantial risks in obtaining heavy production of a product not yet commercially acceptable, has cost the taxpayer many millions of dollars—and may cost him a great deal more.

Interest in titanium, particularly by the airplane industry, merits continued Government support, provided that ultimately the metal can be made properly and produced at reasonable cost.

But based on testimony presented this committee, there is a general lack of coordinated authority with respect to the programs for research, development, and production of the metal.

In this connection, the Acting Director, Materials Division, Emergency Procurement Service, General Services Administration, gave the following testimony:

> The Government has been quite successful in its efforts to increase the production of titanium sponge. However, it has, in my judgment, been remiss in its efforts to assist in solving the technical problems which prevent widespread use of the metal.
>
> As a result of this, the production of titanium metal which during calendar 1954 amounted to 5,370 tons, is estimated at 10,000 for 1955, 17,500 in 1956, and 22,500

in 1957. If the Du Pont contract, presently under negotiation, is executed, production during 1957 may be increased to 30,000 tons.

On the other hand, utilization of titanium sponge amounted to only 1,500 tons in calendar 1954 and is estimated at 1,700 tons in 1955, and no substantial increase can be expected in 1956 and 1957 unless a number of technical problems connected with the alloying and fabricating of titanium can be overcome.

* * * * * * *

The chief difficulty is that there is no centralized authority or responsibility in the Government. * * * There is no centralized direction (on titanium). (Agencies dealing with titanium include the Department of Defense, the Office of Defense Mobilization, the General Services Administration, the Department of Commerce, the Department of the Interior, and the Materials Advisory Board—National Academy of Sciences, National Research Council.)

* * * * * * *

Upon questioning by the committee, the Government representative pointed out that the titanium program has been handled very loosely with an almost total lack of coordination.

The Government knows very little about the actual cost of titanium production as against the sales price.

More complete knowledge of costs should be obtained from the companies the Government is subsidizing, especially as the price of the product depends partially upon the terms of the subsidy.

Government assistance is required to continue projects for improved melting and fabricating techniques. To this end, the committee believes the Director of the Office of Defense Mobilization should transfer the necessary funds to the Department of Defense.

The committee welcomes testimony that an experienced industrialist is coming into the Government to supervise the entire titanium program. It is hoped he will be given adequate authority to carry out his responsibilities.

The committee believes that more money should be utilized in research and development programs for obtaining a better titanium product and relatively less money should be expended in the production of titanium sponge.

Current plans for additional Government financed sponge expansion should be postponed pending more definitive decisions as to requirements and more positive developments in the processing of the sponge.

( )